In the Specification

Applicant presents replacement paragraphs below indicating the changes with insertions indicated by underlining and deletions indicated by strikeouts and/or double bracketing.

Please replace the paragraph beginning at page 1, line 5 with the amended paragraph as follows:

This application claims the benefit under 35 U.S.C. §119(e) to commonly-owned U.S. provisional patent application serial no. 60/442,789, titled IMPROVED HIGH-SPEED MATERIAL SORTING SYSTEM, filed on January 27, 2003 under attorney docket no. S1404.70004US00, ~~and~~ U.S. provisional patent application serial no. 60/442,735, titled SYSTEMS AND METHODS FOR DETECTING ELEMENTS HAVING A LOW ATOMIC NUMBER IN A MASS OF ONE OR MORE MATERIALS AND FOR DETECTING IMPURITIES IN A MOLTEN MASS OF ONE OR MORE MATERIALS, filed on January 27, 2003 under attorney docket no. S1404.70005US00, <u>and U.S. provisional patent application serial no. 60/464,255, titled VARIOUS SYSTEMS AND METHODS FOR HIGH SPEED IDENTIFICATION, CLASSIFICATION, COMPOSITIONAL ANALYSIS AND SORTING OF MATTER AND FOR DETECTING ELEMENTS HAVING A LOW ATOMIC NUMBER, filed on April 21, 2003 under attorney docket no. S1404.70007US00</u>, each of which is hereby incorporated by reference in its entirety.

Please replace the paragraph beginning at page 12, line 19 with the amended paragraph as follows:

In one or more embodiments, the conveying system includes two conveyor belts, with an air gap in-between, over which pieces of material are conveyed from one belt to the other. These one or more belts may be configured to convey pieces of material at any of a variety of speeds, which in one or more embodiments may be as fast as eight feet per second or faster. These one or more belts may be arranged in series, with a first belt having a higher ~~service~~ <u>surface</u> area than the second belt, such that pieces of material may fall from the first belt onto the second belt. Alternatively, the two belts may have a same surface height. In one or more embodiments, the

conveying system may include a single conveyor belt that is transparent to the types of stimuli being used to stimulate the pieces of material and/or to the types of emissions resulting from such stimulation (e.g., XRF or optical emissions). Alternatively, in a single belt embodiment, the single belt may include a substantial open area through which stimuli and/or emissions may pass. For example, the conveyor belt may be a mesh belt or another type of belt that includes openings. Further, in such a single belt embodiment, the single belt may include windows through which stimuli and/or emissions may pass. Advantageously, such windows may define the lower surface of the pieces of material as they are stimulated.

Please replace the paragraph beginning at page 13, line 3 with the amended paragraph as follows:

Each piece of material may be stimulated while passing over one or more sources of stimuli positioned beneath any of an air gap, opening or window described above. Such openings, air gaps and windows enable one or more emissions detectors and/or one or more sources of stimuli to be placed in close proximity to the location at which each piece is stimulated. For example, if a stimulus (e.g., x-rays) causes the piece to fluoresce x-rays, an XRF detector can be placed in close proximity to the location at which the piece is stimulated, regardless of the size or shape of the piece. Accordingly, the XRF detector detects more x-rays fluoresced by low-Z elements before such x-rays are absorbed by air than would be detected if the XRF detector is positioned further away. Further, a laser can be placed at a location beneath the air gap that is a relatively constant distance from the location at which each piece of material passes. As a result, the laser does not have to be re-focused for each piece of material that passes over the air gap. It should be appreciated that the air gap, opening, or [[a]] window, depending upon the embodiment, defines a vertical position of the lower surface of the pieces of materials being stimulated. In the case of a two-belt embodiment, the surface heights and the belt speeds of the two belts may be configured such that when a piece of material is thrown or conveyed across the air gap, it undergoes little change in its vertical position (i.e., in the Z direction).

Please replace the paragraph beginning at page 16, line 29 with the amended paragraph as follows:

A conveying system 220 conveys a singulated stream of pieces of material 202 into a stimulation and detection area 204, which may be an enclosed area, for example, a chamber. Although a singulated stream of pieces is illustrated in Fig. 2, it should be appreciated that in other embodiments, the pieces of materials may be conveyed in parallel singulated streams or randomly-distributed streams. The pieces of material may have been received by the conveying system 220 ~~xxx~~ from any of a variety of sources, for example, a suitable feeder (not shown). The stimulation and detection area 204 may include any of first stimulus source 206, second stimulus source 208, first emissions detector 210, second emissions detector 212 and position detector 214.

Please replace the paragraph beginning at page 18, line 1 with the amended paragraph as follows:

Position detection device 214 may be any of a variety of types of position detection device, for example, a x-ray absorption detector array, an image sensor, other types of detectors, or any suitable combination thereof. In one or more embodiments of the invention, the position detection device 214 may be used to determine a position of the piece within the stimulation and detection area 204. For example, the position detection device may be operable to determine the position of the piece of material in an *x-y* plane with respect to the conveying system 220, where, as shown in Fig. 2, *x* represents the direction in which the piece is being conveyed and *y* represents the direction perpendicular to the direction of movement and parallel to a top surface of the conveying system. As will be described in more detail below, this positional information may be used to aim one or more stimulus sources and/or one or more emission detectors, to produce and detect, respectively, ~~more~~ emissions. Further, this positioning information could be used, for example, by data acquisition and processing module 216 and/or sorting apparatus 218 to sort pieces of material.

Please replace the paragraph beginning at page 18, line 20 with the amended paragraph as follows:

One or more elements 206, 208, 210, 212 and/or 214 of stimulation and detection area 204 may be connected to data acquisition and processing module 216 by network 205. As used herein, a "network" is a group of two or more components interconnected by one or more segments of transmission media on which communications may be exchanged between the components. Each segment may be any of a plurality of types of transmission media, including one or more electrical or optical wires or cables made of metal and/or optical fiber, air (e.g., using wireless transmission over carrier waves) or any combination of these transmission media. As used herein, "plurality" means two or more. It should be appreciated that a network may be as simple as two components connected by a single wire, bus, wireless connection or other type of segment. Further, it should be appreciated that when a network is illustrated in a drawing of this application as being connected to an element in the drawing, the connected element itself is considered part of the network. Thus, the network 205 may be as simple as one or more wires, data buses or wireless connections between the data acquisition and processing module 216 and one or more components residing within the stimulation and detection area 204.

Please delete the following paragraph beginning on page 21, line 9.

~~[Elaborate using language from high-level description or refer to high-level description].~~

Please replace the paragraph beginning at page 22, line 4 with the amended paragraph as follows:

Optionally, the pieces of material fed onto the conveying system 220 may be flattened with a flattening apparatus (not shown), for example, a ~~roll~~ rolls crusher before being fed onto the conveying system 220. By flattening the piece of material, friable materials adhering to the piece of material may be liberated. Further, flattening a piece of material before feeding the piece onto the conveying system improves sorting and classification of the pieces of materials. For example, flattened pieces of material move less on the conveying system, and do not roll as much as non-flattened pieces. Consequently, the position of a piece of material can be

anticipated by the data acquisition and processing module 216. Module 216 may be configured to control the sorting apparatus based on this anticipation so that the piece is properly sorted by sorting apparatus 218. Also, flattening the pieces of material provides a larger surface area to irradiate, and from which to detect x-rays. Consequently, the piece of material is bombarded with, and fluoresces, more x-rays, resulting in a more complete XRF spectrum being determined for the piece of material than otherwise would have been determined. Further, the composition of the piece of material is less influenced by surface contaminants because during flattening fresh material surfaces are exposed, such that a cleaner XRF spectrum is produced. Consequently, the spectrum detected is more representative of the piece of material and not other materials that may be adhering to the surface of the piece of material.

Please replace the paragraph beginning at page 25, line 16 with the amended paragraph as follows:

In one or more embodiments, the first irradiating x-rays 322 produced by the first x-ray source 306 are within a first energy range, and the second irradiating x-rays 324 produced by the second x-ray source are within a second energy range 308. For example, the first x-ray source 306 may produce x-rays 322 spanning a relatively full energy range, and the second x-ray source 306 may produce second irradiating x-rays 324 limited to a narrower and lower energy range (e.g., an energy range within which low-Z elements fluoresce x-rays). By producing more x-rays within the lower energy range, the likelihood of detection of the low-Z elements, for example, aluminum, magnesium, silicon, etc., is increased. This increased likelihood of detection results for the following reasons. The more intense x-rays increase the likelihood that the irradiating x-rays from the x-ray source will reach the piece of material. Further, the higher intensity increases the likelihood that the sparsely-spaced elections of low-Z elements of the piece will be impacted and dislodged, as opposed to the irradiating x-rays ~~transmitting~~ passing through the low-Z elements without impact. This is analogous to spraying a fire hose as opposed to a garden hose at a collection of sparsely-spaced objects. The stream of water from the garden hose is far more likely to pass through the objects without hitting them than the stream of water from the fire hose. Thus, the fluoresced x-rays 326 include a higher number of x-rays fluoresced from

low-Z elements than otherwise would be fluoresced. As a result, more x-rays fluoresced from low-Z elements reach x-ray detector 310 without being absorbed in air. For example, the first and second x-ray sources may be configured such that the first irradiated x-rays 322 range in energy from 0 keV to 30 keV or greater, and the second irradiated x-rays 324 have energies of 4.5 keV or lower. To produce x-rays of 4.5 keV or lower, the second x-ray source 308 may be an x-ray tube having a Ti target of $K\alpha = 4.5$ keV. Optionally, the second x-ray source 308 may be operated at an extremely high output flux, thereby increasing the count of irradiated x-rays 324, for example, by orders of magnitude (e.g., by ten, one hundred, one thousand, ten thousand, or even more). If the piece 202 being irradiated contains low-Z elements, this increased amount of irradiated x-rays 324 having an energy of 4.5 keV or lower produces an increased number of fluoresced x-rays 326 from low-Z elements having an energy level 4.5 keV or less.

Please replace the paragraph beginning at page 33, line 24 with the amended paragraph as follows:

As indicated by the arrows throughout Fig. 7, the photons emitted from the piece of material 202 then may be passed back through many of the same components through which the light of the laser beam passed before hitting the piece of material. Thus, fiber optics cable 712 may include one or more ~~include~~ strands that transmit the light that impacts the piece of material 202 and one or more strands that transmit the optical emissions emitted from the piece. Accordingly, the emitted photons pass back through lens 714, through fiber optics cable 712, through lens 708 and into lens 716. Lens 716 focuses the emitted photons onto a fiber optic cable 718, which leads to data acquisition and processing module 216. It should be appreciated that other embodiments of a vaporizing and detecting unit may be used.

Please replace the paragraph beginning at page 34, line 3 with the amended paragraph as follows:

The vaporizing device 608 of Fig. 6 and/or the laser 702 may be configured to generate multiple pulses of light with each piece of material. For example, the first one or more pulses may be used to vaporize surface contaminants (e.g., oxides) from the surface of the piece being

eradiated. After the service contaminants have been cleared by the first one or more pulses, the last pulse may be used to vaporize a portion of the piece of material to produce the optical emissions on which the classification on which the piece is based. Accordingly, system 600 may include control ~~circuit fee~~ logic to control the timing of the detection of optical emissions to coincide with the pulse that vaporizes a portion of the piece of material, as opposed to mere surface contaminants on the piece of material. Such control logic may reside within the data acquisition and processing module 216, within the vaporizing and detecting unit 413, ~~and~~ within another component, or may be shared between one or more components of system 600.

Please replace the paragraph beginning at page 34, line 15 with the amended paragraph as follows:

Fig. 8 is a block diagram illustrating an example of a system 800 for classifying and sorting pieces of material 202 using XRF spectroscopy and Arc Discharge Spectroscopy (ADS). System 800 includes several of the same components described above in relation to Fig. 6. Instead of having a vaporizing device 608, for example, a laser, system 800 includes an arc discharge device which includes a power source 708 and electrodes 711 and 713. Power source 708 is enabled to build up a charge between nodes 711 and 713. When a piece 202 is not present between electrodes 711 and 713, the charge remains on the electrodes because the air between the electrodes serves as a dielectric. When a piece 202 passes between electrodes 711 and 713, a conductive path is created between the electrodes causing electric discharge 715, 717 to vaporize a portion of piece 202. The vaporized portion becomes a plasma that emits optical emissions 626.

Please replace the paragraph beginning at page 34, line 27 with the amended paragraph as follows:

In one or more other embodiments, spark discharge spectroscopy (SDS) may be used instead of ADS. In contrast to ADS, in SDS a spark is continually present between electrodes 711 and 713 (e.g., similar to a welding gun). The spark vaporizes a portion of piece 202 as it passes on the producing plasma which emits the optical emissions 626. SDS, which often is used

in a laboratory environment, typically requires operation in less than an atmosphere ~~or~~ of pressure, for example in Argon. Further, SDS typically is slower in classifying materials than ADS. Accordingly, it may be desirable to use ADS over SDS.

Please replace the paragraph beginning at page 36, line 4 with the amended paragraph as follows:

The spectrum acquisition module 918 also may include an optical spectrum acquisition module 922, which may receive optical photon information 912 and produce an optical spectrum 928. The optical photon information 912 may be received from optical emissions collector 412 or a similar component. The optical spectrum acquisition module 922 may be any of a variety of types, for example, an OES ~~spectrograph~~ spectrometer.

Please replace the paragraph beginning at page 36, line 14 with the amended paragraph as follows:

The spectrum information 924, which may include any of XRF spectrum 926 and optical spectrum 928, is sent to classification module 930. Classification module 930 may employ classification techniques, ~~including the classification module 930~~ and may be configured to implement any of Acts 1104-1110, described below in relation to Act 1100. The classification module 930 may compare the spectrum information 924 to emissions information 936 stored in materials database 934, which may reside on a same or different device than classification module 930. The emissions information 936 may include XRF information 938 and optical information 940. The XRF information 938 may include a library of reference spectra and/or a reference ROI vectors. The optical information 940 may include a library of optical spectra and/or reference ROI vectors. By comparing the spectrum information 924 to the emissions information 936, the classification module may determine a best match for the piece of material, or that there is no match, and provide the appropriate information to the sorting interface 932. The sorting interface 932 then may provide the sorting instructions 942 to the sorting apparatus 944 in accordance with the classification.

Please replace the paragraph beginning at page 37, line 1 with the amended paragraph as follows:

In one or more embodiments, the XRF information 938 and the optical information 940 are not separated collections of ~~informants~~information, but are one integral collection of information. For example, for a given reference material, a reference spectra and/or reference ROI vectors may include both optical and XRF information.

Please replace the paragraph beginning at page 38, line 3 with the amended paragraph as follows:

In one or more embodiments, no optical ~~photo~~photon information 912 and/or positioning information 904 may be received by module 216. In such embodiments, module 216 may not include optical spectrum acquisition 922 and/or positioning module 914. Alternatively, these components may be ~~disable~~disabled, turned off or not used.

Please replace the paragraph beginning at page 38, line 30 with the amended paragraph as follows:

Those of skill in the art should ~~be appreciated~~ appreciate that the various settings and parameters of the components of systems 200, 300, 600, 700. 800 and 900, including data acquisition and processing module and its components, may be customized, optimized and reconfigured over time based on the types of materials being sorted, the desired sorting results, the type of equipment being used, empirical results from previous sorts, data that becomes available and other factors.

Please replace the paragraph beginning at page 40, line 11 with the amended paragraph as follows:

In Act 1012, the piece may be sorted based on the classification, for example, ~~for~~ by activating an air jet or other mechanism for removing a piece of material from the conveying

system into an appropriate location, for example, a sorting bin. Any of a variety of techniques may be used to sort based on the classification, for example, using any of the techniques described above.

Please replace the paragraph beginning at page 40, line 25 with the amended paragraph as follows:

In Act 1104, a region of interest (ROI) vector may be determined for each of the one or more spectra. Although a determined spectra may ~~have~~ include discrete energy counts spanning a wide range of energy levels and/or wavelengths, it may be that only certain energy levels or wavelengths are of interest in classifying a piece of material. Such energy levels and/or wavelengths may serve to distinguish classes of materials from one another. However, even though the specific energy levels and wavelengths at which elements produce emissions can be used to distinguish classes of materials, the equipment used to capture emission spectra (e.g., XRF detectors, optical emissions collectors, and XRF and optical acquisition modules) are imperfect devices. Thus, the captured emissions spectra may not perfectly reflect the energy levels and wavelengths of the emissions that were actually emitted from a piece of material. For example, although an element (e.g., titanium) may fluoresce x-rays at a specific energy level (e.g., 4.51 keV), an XRF detector may only have a resolution of 0.25 keV. Further, although the XRF detectors may detect a peak intensity at 4.50 keV for this element, the XRF detector also detects XRF at other energy levels in a distribution pattern around 4.50 keV.

Please replace the paragraph beginning at page 41, line 19 with the amended paragraph as follows:

In Act 1106, the ROI vector may be normalized using any of a variety of normalizing functions. For example, the ROI vector may be L1 or L-Infinity normalized. For example, using L1 normalizing, each ROI value may divided by the sum of all of the ROI values, whereas using L-Infinity normalizing, each ROI ~~vlaue~~ value may be divided by a maximum value. Normalizing the ROI vector may reduce the effects from variances in surface areas of the pieces of material that are sorted and the surface areas of the reference spectra. Further, normalizing the

ROI vector also reduces the effects of variances in the irradiation flux of the one or more stimuli, variances in the fluorescent yield of each piece of material and reference sample, and variances in the acquisition times for pieces of material and reference samples.

Please replace the paragraph beginning at page 41, line 29 with the amended paragraph as follows:

In Act 1108, for each ROI of the ROI vector, a peak value of the ROI may be estimated. For example, a shaping function may be applied to the ROI value for each ROI in the ROI vector. Any of a variety of shaping functions may be used, for example, a Gaussian distribution function, a Poisson distribution function or another suitable function. If a Gaussian distribution function is used, then the Full Width Have Maximum (FWHM) technique may be used. By applying a shaping function to each ROI value, the peak value of a mature spectrum may be predicted (i.e., estimated) from the immature spectrum built from the detected first and second emissions. This technique for estimating a peak value for the ROI enables an accurate classification to be made for a piece of material even though the emissions were detected for the piece of material over a very brief period of time, as short as 10 milliseconds or less. Accordingly, pieces of material can be sorted at a much faster rate than they otherwise could be sorted. Further, by reducing an entire spectra of emissions data to a vector of values, namely a vector of estimated peaks, the amount of data that must be subsequently analyzed to classify the piece of material is substantially reduced. This reduction of data ~~reduced~~ reduces the amount of computations that must subsequently be performed, which further increases the rate at which pieces can be sorted.